ACTIVITY AND PERSISTENCE OF SYSTEMIC INSECTICIDES FOR MANAGING HEMLOCK WOOLLY ADELGIDS

Richard S. Cowles[1] and Anthony F. Lagalante[2]

[1]Connecticut Agricultural Experiment Station, Valley Laboratory, Windsor, CT 06095

[2]Villanova University, Department of Chemistry, Villanova, PA 19085

ABSTRACT

Systemic insecticides have protective and therapeutic value for managing hemlock woolly adelgid in forests (Webb et al. 2003, Cowles et al. 2006, Cowles 2009). Although use of insecticides in forests for managing this pest cannot be considered a sustainable long-term strategy, systemic insecticides are an effective option for maintaining the health of hemlock trees so that they can continue to provide ecosystem and aesthetic functions until such time that biocontrol or plant resistance become established.

Two systemic neonicotinoid insecticides, imidacloprid and dinotefuran, are effective for managing hemlock woolly adelgids. Imidacloprid has been available for use in landscapes since about 1993 and has been extensively studied. Ever since it was first evaluated in the landscape against various hemipteran pests, multiple-year benefits have been observed (Cowles and Cheah 2002, Cowles et al. 2006, Cowles 2009). It remains unknown if the multiple-year benefit has been due to extreme efficacy within the first year after application, resulting in defaunation within a tree and slow decolonization, or if it is due to the continued presence of effective titers of insecticide. Because imidacloprid is a semi-polar compound with complex metabolism within trees, addressing this question has had to wait until analytical equipment of sufficient sensitivity became available. High performance liquid chromatography used with tandem mass spectrometry (LC/MS/MS) is well suited for this task because the parent compound and metabolites can be selectively analyzed and sensitively quantified at part per billion (ppb) concentrations. Although ELISA methods have been useful in the past to obtain rough estimates of imidacloprid concentrations in tissues, these results were semiquantitative because imidacloprid metabolites could contribute to falsely elevated imidacloprid readings and the relative role of parent compound and metabolites remained unknown (Cowles et al. 2006).

Multiple years of field tests using standard application practices for imidacloprid provided an opportunity to explore the long-term metabolism of imidacloprid within hemlocks. Trees treated with soil injections of imidacloprid in 1999, and consecutive years from 2002 to 2006 in Connecticut and Pennsylvania, were sampled during the autumn of 2007. Foliage from new growth was dried, pulverized, extracted with acetonitrile, and analyzed by LC/MS/MS. Other samples taken within the first year of soil or trunk injection were provided by Rick Turcotte, U.S. Forest Service, Morgantown, WV. Analyses revealed that imidacloprid titers peaked approximately 2-6 months after trunk injection and 18-20 months after soil injection. Titers fell below ~100 ppb in about 3 years, but remained detectable 8 years after treatment. Imidacloprid metabolized readily to its olefin, known to be 10-16× as active as the parent compound (Nauen et al. 1998, Nauen et al. 1999). The concentrations of this metabolite parallel and are equivalent to those of imidacloprid until about 5 years after treatment, at which time the imidacloprid residues decreased while the olefin metabolite remained stable. Therefore, we conclude that the high degree of adelgid suppression is due to the continued presence of imidacloprid and imidacloprid olefin, which continued to translocate to new growth over several years. Mortality is compounded over multiple generations, so that a single soil application can provide 5-7 years of protection. Trunk injected trees have average insecticide and metabolite titers similar to trees treated through soil injection. Therefore, poorer efficacy resulting from trunk injection methods is due to uneven distribution uniformity.

Dinotefuran is a highly water soluble and extremely upwardly systemically mobile compound compared to imidacloprid (EPA 2004). It was first registered for use in the landscape in 2005. A test of this product for hemlock woolly adelgid in Connecticut compared application of 0.75 g active ingredient per inch d.b.h., applied either through shallow subsurface soil injection or applied with the organosilicone surfactant PentraBark® as a spray to the lower 1.5 m of the trunk. Application in early October, 2007, resulted in adelgids dying at branch tips on new growth within 2 weeks. Those adelgids developing on 1-year-old growth required a longer time to die, as evident from a greater amount of wool. Mortality of sistens in 2007 was approximately 80 percent with each of these two application methods. One year later, the populations of sistens were reduced by 100 and 96 percent, respectively, for soil vs. trunk spray application methods for Safari when compared with untreated controls; the results from these application methods do not significantly differ. Although residue data for dinotefuran in hemlock tissue has not been completed, it is expected from metabolism studies in other plants that it may not provide adelgid control beyond the second year following application.

The differences in systemic mobility and residual activity between imidacloprid and dinotefuran reveal complementary temporal properties. Imidacloprid is probably best suited for protection of trees at the infestation front, before decline in tree health occurs, or in areas where populations of adelgids have been reduced by low winter temperatures. It is mobilized so slowly through trees that the full effects of soil treatment are not observed for at least 1 year following application. Effects are even slower when using the slow-release tablet formulation, CoreTect®, which can take 1 year longer than the wettable powder or flowable formulations to achieve adequate control. In the southern Appalachian mountains, where the largest trees may succumb about 3 years after initial infestation (Will Blozan, personal communication), treating already stressed trees with imidacloprid may not provide the rapid adelgid reduction needed to preserve a tree. Dinotefuran can quickly reduce populations of adelgids, a property that is especially important for stressed trees. The availability of a trunk spray application method should mitigate environmental contamination with this insecticide. Although held less tightly by organic matter than imidacloprid, any residues leaching from bark with subsequent rainfall would be expected to bind to soil organic matter or be degraded by light on the soil surface. Where labor costs due to difficult access to trees is an overriding component to the cost of chemical treatment, combining the rapid effect of dinotefuran with the slow-acting but longer-lasting effects of imidacloprid should be considered, especially where exceptionally valuable trees are already experiencing stress from adelgid feeding.

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